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(54) **Automatic Score Translator**

(57) An automatic score translator has a multiplicity of sensors which identify the location of a target board hit by a projectile. Sensors are arranged at the rear side of the target board and an electronic circuit receives the analogue sensor outputs and resolves them into a single signal which identifies the marginally largest sensor output.

A projectile may contain a permanent magnet and the sensor system responds to field variations created by the arriving projectile. The score data selected is processed by an arithmetic circuit which may include a memory register, display encoders and a printout unit.

Alternatively, a combination may be used of intensity and time lag differences in the propagation of an impact pulse created by the projectile on the board. Pressure sensitive elements are mounted on the rear of the target board and their outputs are fed to an electronic circuit which compares time lag and intensity levels of the impact pulse at different rear-board locations.
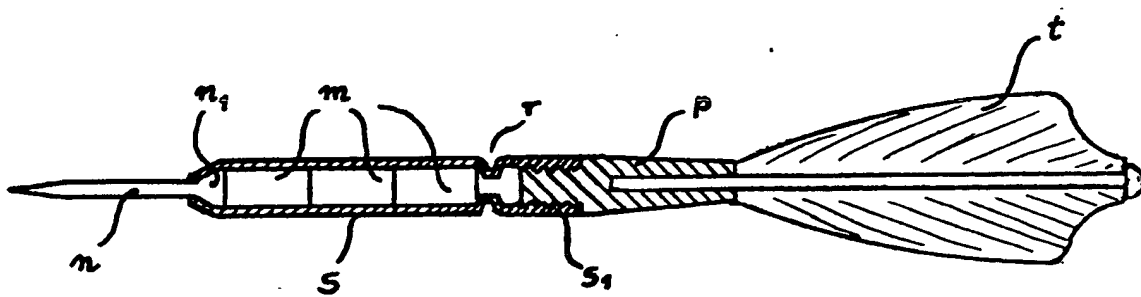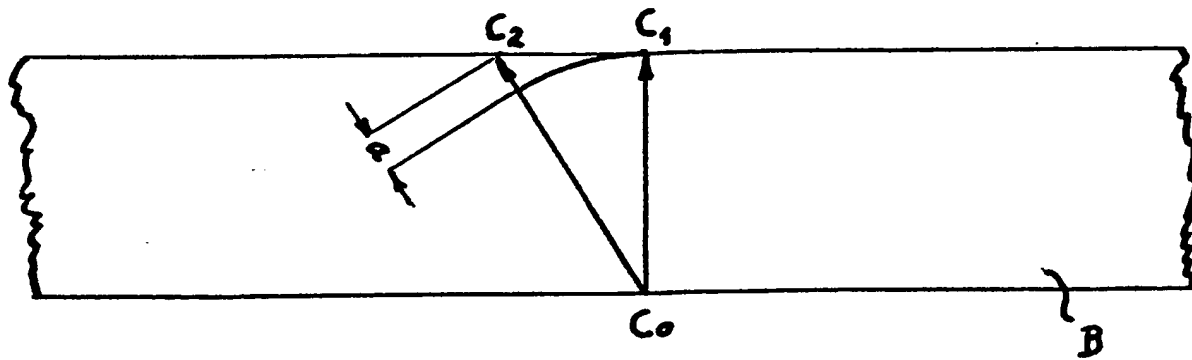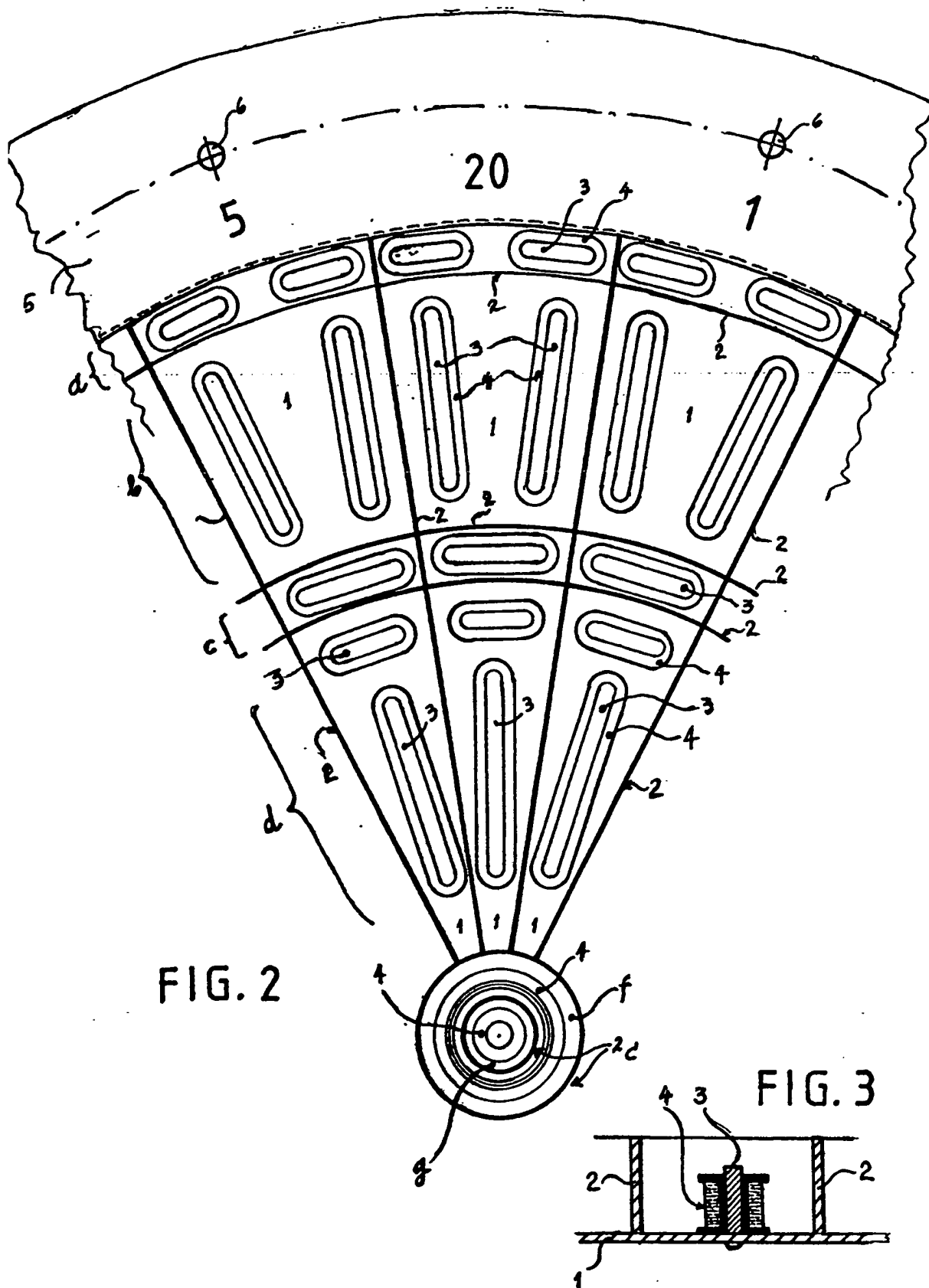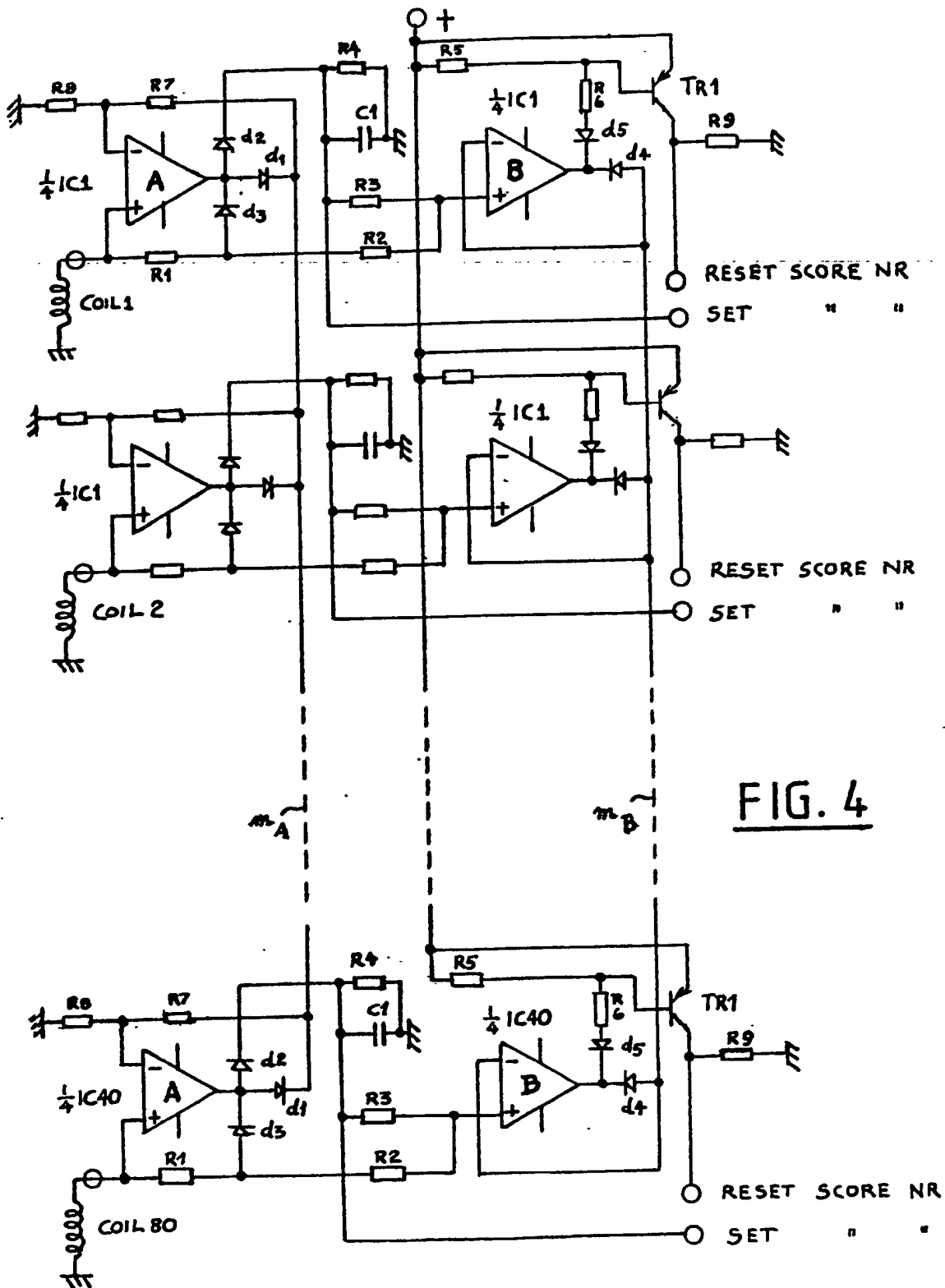
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FIG. 1

FIG. 6

FIG. 2

FIG. 3

FIG. 4

FIG.5

FIG.7

VIEW A-A

FIG.8

SECTION b-b   a-a   c-c

A
A

VIEW B-B

FIG.9

FIG. 10

B ↑

B ↑

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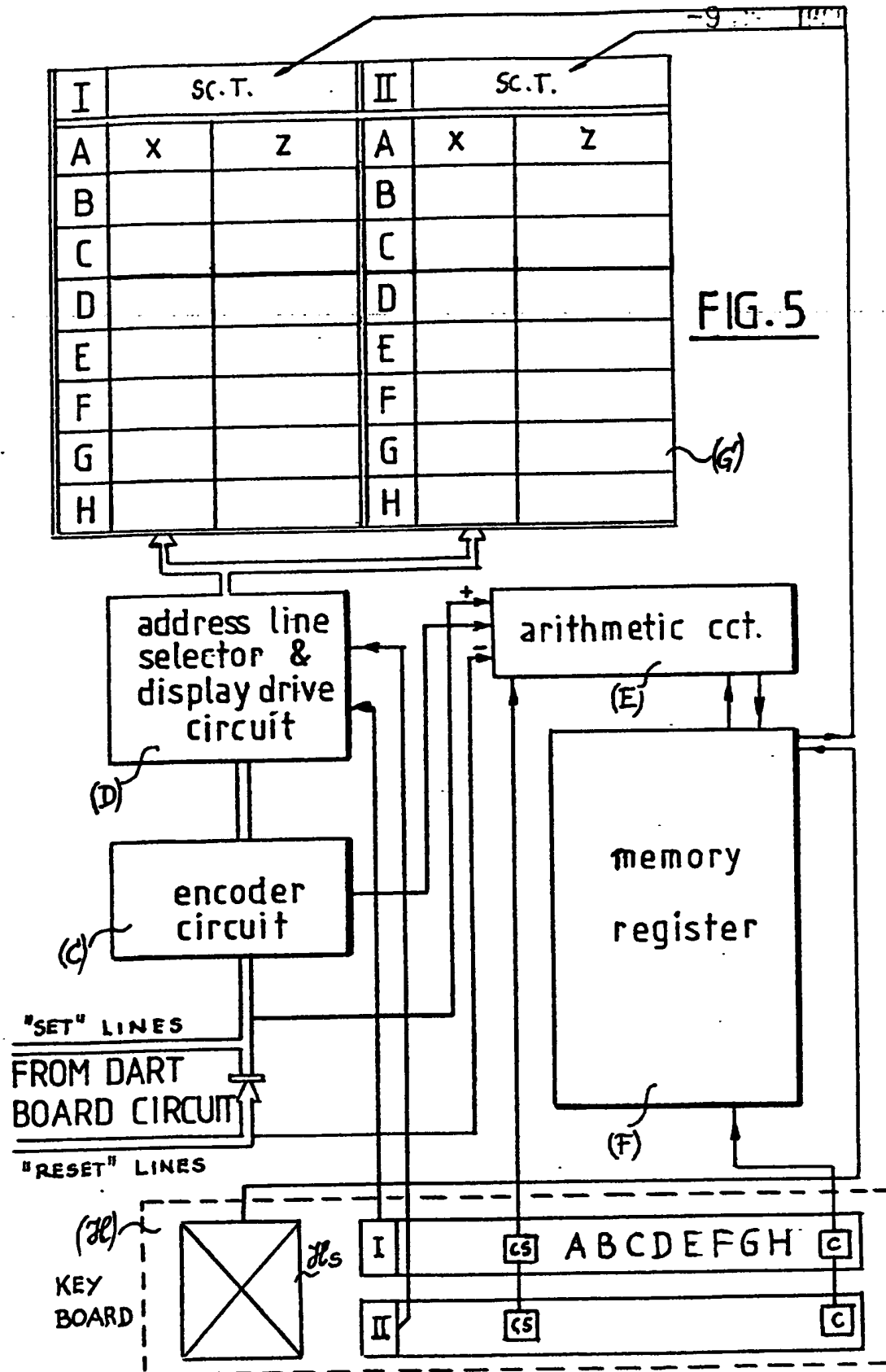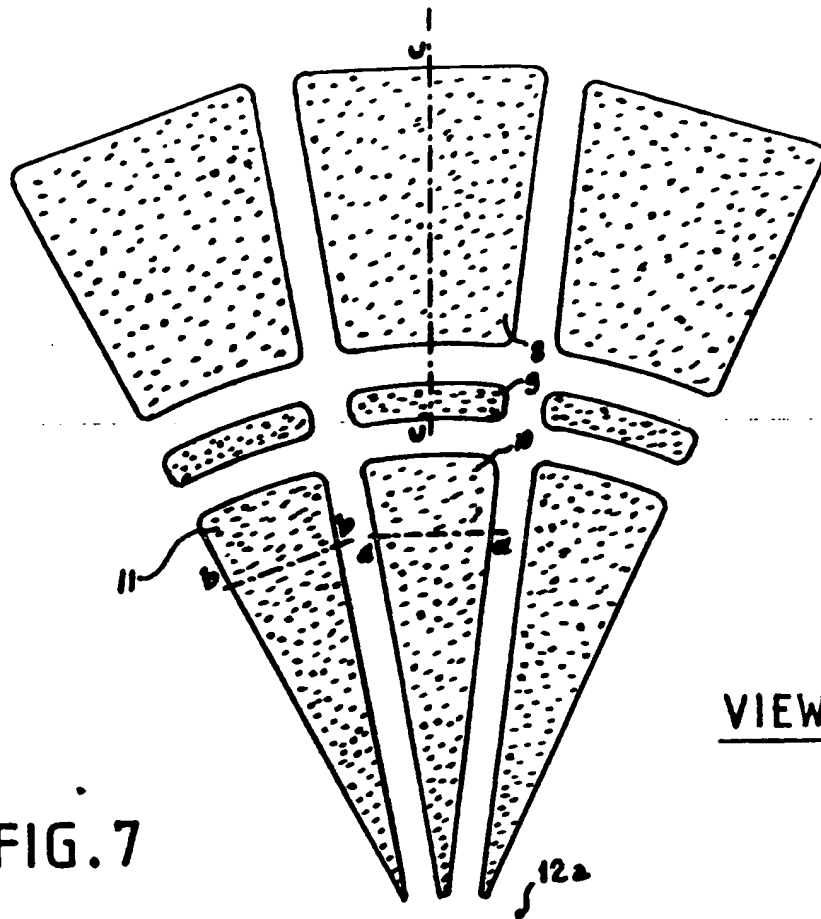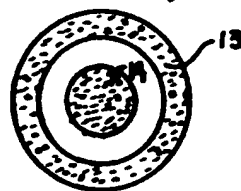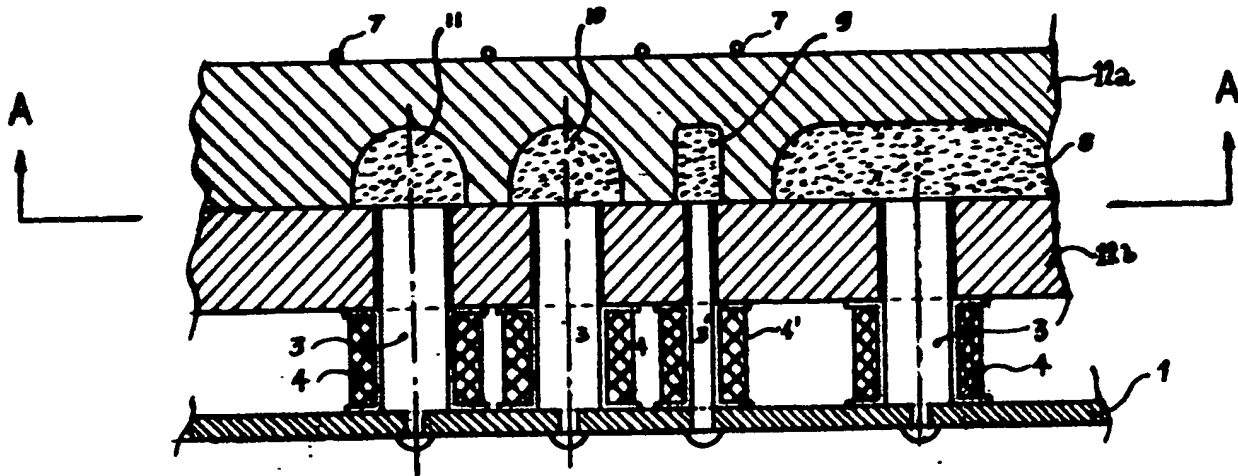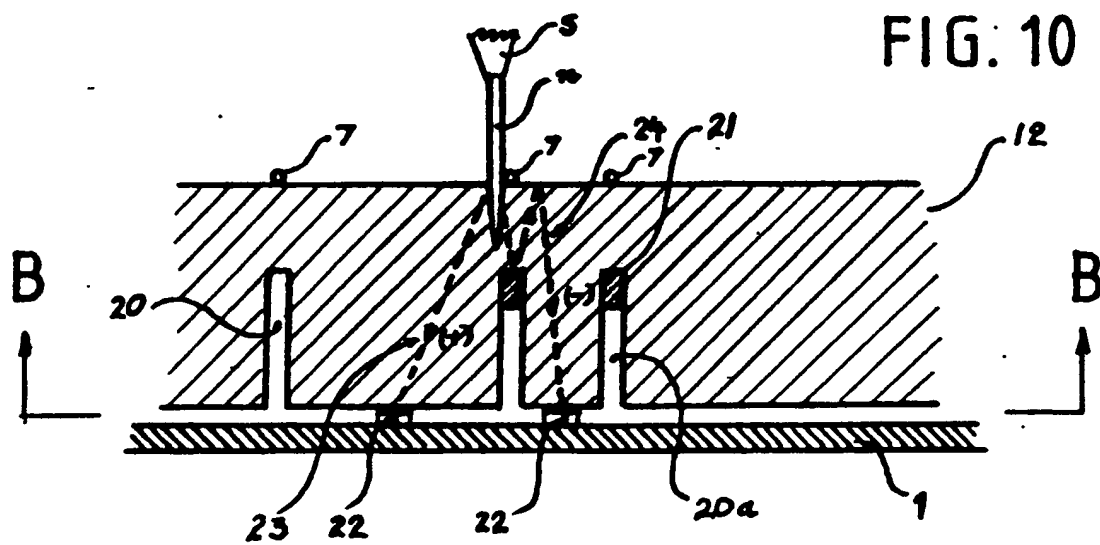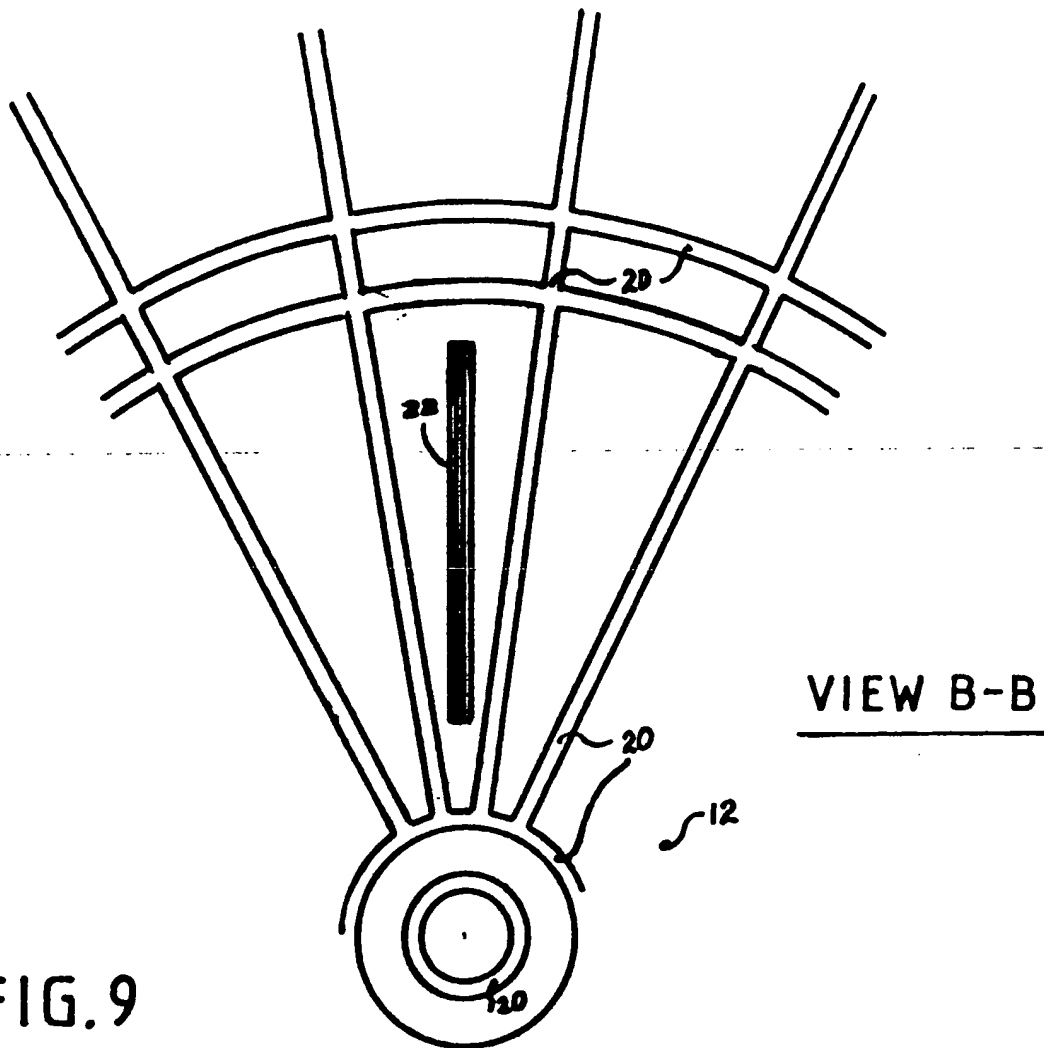
SPECIFICATION
Automatic Score Translator System in Projectile Games

The present invention relates to a basic system
5 for sensing and identifying the segment of an area
upon which targeting shots with any kind of
projectile are directed. To this category belong
various games such as archery, crossbow, stone
or dart throwing, as also training sites for sharp
10 shooting. In these instances it is often difficult to
arrange for observers to be near the target area,
and assessment subsequent to the projectile
impact is cumbersome, open to error or
uncertainty, and wasteful of time. In some games
15 there arises a danger to the assessor in that he
may not have left the projectile throw orbit before
the next round starts. In many games as dart
throwing there exists an additional need to hold
fast the results, usually by chalking them up on a
20 blackboard.

Taking the dartboard as the primary example
for explaining the invention principles it can be
said that there are several reasons for trying to
replace a human score assessor and writer of the
25 score list. One of them is that it is a cumbersome
task to chalk up and delete in quick succession
the various score numbers of the participating
players. Not always is the right person at hand for
this task. The frequent deleting and re-writing of
30 the numbers on a blackboard tends to be a messy
job, the chalk settles on furniture, a carpets and,
on the participants' lungs. These circumstances
make the game less acceptable in elegant homes
and pubs.

35 Proposals such as exist to 'automatize' the
score listing are mainly bound up with a complete
re-design of the dartboard itself. These attempts
did not prove very successful because traditional
boards are based on long manufacturing
40 experience which cannot be disregarded.

This present proposal assumes from the
beginning that traditional target boards should be
usable; the required sensor mechanism for
identifying the projectile location constitutes a
45 separate entity which is attachable to the target
board from the rear.

The effect which the throwing of a projectile
can have on sensors arranged at the back of a
target board depends on the nature of the forces
50 sensed.

This proposal describes an example wherein
the forces to be detected are magnetic, but the
principles of the electric detection circuits by
which the individual sections of the board hit by a
55 projectile are identified may also be used in
conjunction with other type of sensors, such as
for example sensors detecting differences of
propagation time of the impact pulse, or sensors
for voltage gradients emanating from a projectile
60 charged with static electricity. In all such cases a
projectile landing on one sector of the board will
inevitably affect also sensor sections belonging to
neighbouring board sections. There will be
differences in the intensity or time sequence of

65 the sensed forces but these differences are likely
to be small especially when a projectile lands
close to a section border.

It is therefore one feature of the invention that
it deals with the problem of safely selecting the
70 largest sensor signal among several others
generated at the same time. Or, as already
referred to in an alternative form with selecting
the first signal among others following at very
short intervals.

75 Another feature of the invention is the design
of a projectile suitable for throwing games (i.e.
dart) which is rendered suitable for magnetic
detection techniques. Therewith connected are
specific proposals for forming out a sensor
80 suitable for being mounted to the back of a target
board and for converting rapidly rising or falling
magnetic fields into an electric signal.

Details of the invention will now be described
with the aid of the enclosed drawings in which
85 Figure 1 shows a dart according to the
invention

Figures 2 and 3 show portions of the rear
sensor assembly

Figure 4 shows the circuit for producing a
90 unique output from the sensor with the largest
signal while the remaining output terminals
switch to or remain at zero logic level output.

Figure 5 shows a block diagram of the
electronic system which uses the outputs from
95 the Fig. 4 circuit and is programmed by means of
a key board

Figure 6 illustrates the impact propagation
delays at the back of the target board

Figure 7 and 8 modifications to target
100 board/magnetic method

Figure 9 and 10 modifications to target
board/pulse sensor method.

Figure 1 shows an example of a magnetic dart.
n is the dart needle made of magnetizable steel; it
105 thickens conically at the rear end n_1 to match the
diameter of rod magnets m. Normally one rod bit
m would suffice and the remaining bits may be
made of brass or aluminium or plastics dependent
on the weight requirement; on the other hand
110 inserting two or three magnet bits in tandem
would increase the magnetic field. Needle and
magnets are inserted into a sleeve s made of
suitable material. A recess r pressed or spun on
after assembly holds the magnet piece(s) firmly
115 pressed against the needle extension n_1. The
stabilizing tailend t together with a plastic holder
p may be inserted from the rear in the known
manner. As a result of this arrangement the
needle tip becomes magnetically polarized the
120 field of which is noticable over a distance of 2—3
inches.

Figure 2 is an elevation of the sensor assembly
as viewed from the rear surface of the dart board
(looking in the direction towards the wall behind).
125 The circular bottom plate 1 carries
perpendicularly thereto inserted or riveted-on
inductor cores 3 made of iron. Around each such
core is placed a bobbin and coil 4. These sensor
coils are placed into section areas which are

completely congruent with those of a standard
dart board. These areas are defined by the
magnetic shielding divisions 2. (See also a cross
section, Figure 3). The ring areas a, b, and d have
5   two serially connected sensor coils per sector.
Ring area c has only one coil per segment
according to this example. The central ring area f
and the center core g have one coil each.
Although also these areas have magnetic shield
10   walls (2c) it may turn out that these are
inadequate for differentiating these two central
areas. In that case supporting means discussed
further below may be employed. The entire sensor
assembly has a flange 5 with holes 6 at
15   predetermined positions. One may provide pins in
the dart board which serve as location pins so
that the assembly may quickly be fitted or re-
fitted to any board with assurance of proper
alignment of all the sections.
20   While the example here given is based on the
sensing of magnetic field changes, similar or
analogous arrangements may be designed for
sensing electro-static fields or mechanical impact
pulses already referred to. In all instances the
25   main problem is of how to identify the sector with
the largest signal (or with the first signal
respectively) while completely ignoring all others
having perhaps only marginally smaller (or
delayed respectively) signals. This problem has
30   been solved by adapting a technique already
known for amplifying only the largest signal out of
a multiplicity of signals. (See Jerald G. Graeme,
"Designing with Operational Amplifiers"
published by Burr-Brown, page 95). In our case,
35   however, not the amplification of the largest
signal is of interest but identifying the location of
the source of the largest signal of positive polarity
and the largest signal of negative polarity (if any)
by clearcut logical level output signals. This is
40   achieved by means of circuit Figure 4. On the left
can be seen the 80 or 82 coils of the sensor
assembly Fig. 2. Each coil is associated with two
operational amplifiers A, and B. These circuits
may with advantage be obtained from integrated
45   packages such as Fairchild μA-4136 which
contains four such IC's in a single 14-pin dual in
line package. Eighty coils can therefore be served
by 40 packages which can readily be
accommodated on two circuit cards together with
50   associated discrete components.
    In the example Figure 4 the voltage induced in
the coil is applied to the non-inverting inputs of A
and B. Where a positive e.m.f. is excited by the
approaching dart magnetic field, amplifier A will
55   produce a positive output signal amplified by the
resistance ration R7 plus R8/R8. It will now be
observed that all the amplifiers 'A' are connected
together on the output side after diode d_1 by
means of a common conducting rail m_A. Assume
60   that an unspecified number of the coils (1—80)
produce simultaneously output voltages of similar
shape along the time axis but of different
amplitudes—such as is likely to occur when a
dart is thrown at a dart board. The rail m_A will be
65   charged up to the highest amplified signal

available from any of the 80 amplifiers. As this
voltage is fed back to the inverting side of the
inputs via voltage dividers R7, R8 *only one*
amplifier can produce the desired positive output;
70   namely that which has the largest coil signal. All
the others will receive at the feedback input more
positive voltage than is needed for the
amplification limitation given by the said
resistance ratio, that is to say the limitation would
75   be heftier than required and thus swing the
amplifier output into the negative range. It is thus
possible to connect an output terminal called 'Set
Score Number' to each diode d_2 well knowing
that only the highest positive voltage swing
80   associated with a particular coil will drive this
output to logic 1 whereas all the others remain at
logic zero.
    Now, the magnetic field of the dart can also
generate a negative voltage excursion in any of
85   the coils; this happens when the magnetic field is
receding, that is to say when the dart does not
stick well in the board but drops out and falls to
the ground. In this instance, of course, the score
selected must be cancelled again. A negative
90   input voltage at amplifier 'A' will be fed back via
diode d_3 and thereby reinforce the negative
voltage applied to input resistor R_2 of the amplifier
'B'. The same is connected in a voltage follower
configuration via diode d_4. The output signal, if it
95   is negative, will be passed on via diode d_5 to the
gate of transistor TR1 which becomes conductive
so that the voltage drop across resistor R9
produces a logic high at the terminal 'Reset Score
Number'. Again, all the amplifiers 'B' are
100   connected together, via conductive rail m_B, and
thus only the largest negative signal is capable of
producing the said logic output.
    Means have to be provided to prevent the
natural oscillation of a coil which after a positive
105   swing may well dip into the negative range, from
causing a faulty 'reset' output. To this end the
resistor R_3 is provided which when capacitor C1
charges positive after the first positive swing, acts
like a summing resistor thereby counteracting any
110   subsequent negative swing applied to R1. The R-
C constant of the capacitor C1 and the resistor R4
would be so dimensioned that the sum of the
positive and negative input currents to amplifier
'B' is approximately zero, or preferably remains a
115   little positive. This would exclude amplifier 'B'
from being affected by the decaying oscillations in
the coils after a dart arrival.
    Figure 5 shows how the 'SET' and 'RESET'
outputs from the sensor board are used. Each
120   'SET' output encodes a definite score number in
the unit '(C)' which is then latched and causes a
subtraction from the instant total in the arithmetic
unit '(E)'; and each RESET output encodes the
same score number in unit '(C)' but causes it to be
125   added to the instant total in the arithmetic unit
'(E)'. Via the memory register '(F)' the arithmetic
unit may also control the displays X and Z on the
display board '(G)'; therefore, a RESET output
would for example also cancel the display of the

score number in column X, and enter the preceding total under column Z.

The memory register '(F)' also receives inputs from the keyboard '(H)' which has the following
5 keys: Two rows of participants letters A to H; two team keys (I and II) to signify to which team a player belongs, and a dial board H_s which enables start totals for each side to be selected and displayed at SC.T. If only two persons play, then it
10 is sufficient to key in I and II, dependent who starts first. In a simplified form, no keyboard at all would be necessary when the convention is implemented that the score is entered on the left side for whomsoever starts first followed by a
15 display on the right for the score of the partner, even irrespective of the numbers of players in the team. The arrangement according to Figure 5 is optional where it is believed to be of value of highlight also individual performance not merely
20 team performance. With this equipment it is not essential that players keep to a definite sequential order. For example the first player may be one in team II having allotted to him the letter C. Accordingly the combination C–II would be
25 selected on the keyboard whereby the score encoder and the arithmetic unit are put into a state of readiness to receive instructions from the sensor assembly via circuit Figure 4. After the first dart the number scored appears in line II–C under
30 column X. Simultaneously the difference between the start total and the present score is displayed under column Z on line II–C. The memory unit stores the result. The next player may be I–B, and the third player be II–A. To begin with the reduced
35 start total is shifted into the II–A line under column Z while the score of the previous player II–C extinguishes (though kept in memory). The scores obtained by the third player are now displayed under column X. And so on. What
40 concerns the display of the score, there is also a usage which prescribes that the score should be displayed only after the third throw. This can of course be implemented by logic incorporated in the arithmetic unit which automatically adds up
45 three consecutive score numbers and thereafter blocks any further numbers until a push button mounted near the dart board is actuated whereafter the score display appears. This may then remain until the next player of the same
50 team has thrown his/her darts and then causes the score to be displayed in the manner just indicated. The scores achieved by each individual player may be further processed by producing aggregates, for performance comparison.
55 However, scores below a certain remnant totals figure are not counted, and this again would be executed automatically through incorporation in the system program.—The play is thus divided in a first portion called the 'scoring play' which lasts
60 until for each team the preset lower remnant total is reached, and the 'finishing play' wherein players do no longer concentrate on obtaining the highest scores but rather on planned precise scoring so that in the course of three throws the remnant
65 total is reduced to zero. The performance quality

of players is then reflected on the one hand in the average scores obtained in the first part of the game. To hold all the data in the memory bank '(F)' and finally to process them for the obtaining
70 of the evaluation figures just mentioned, will be part of the instruction imparted on the Figure 5 data processing system.

When the display board is full, that is to say when each of the players of a team have had their
75 turn of three darts, the key 'C' is depressed whereby the residual totals are carried forward and the SC.T. displays are changed accordingly.

When during the finishing part of the game a score is obtained which would cause the residual
80 total to go negative, the electronic circuit would be arranged to cancel this result and recall the preceding residual total and display it again—in other words to render the last score fully ineffective.
85 A more developed automatic score translator may also comprise a programming key board enabling players to modify the game rules in accordance with various versions of the game.

It has earlier been mentioned that the selection
90 of the 'bull' center and surrounding ring respectively might turn out to pose difficulties. If that occurs it is suggested that the center portions of the board may be made of an insert core and ring, its material being impregnated in its
95 middle areas by iron dust particles. This would introduce a sharper definition of the narrow areas in relation to the pickup coils thereunder and thus restore the sensitivity to the required minimum difference signal levels. This principle could be
100 applied to all the narrow segments as well.

In outdoor target boards the individual segments are likely to be larger and therefore it might be possible to employ the impact pulses passing through the board as the criterium for
105 location detection.

The principle is explained by means of Figure 6. When the projectile hits the target board 'B' at the point C_0 the impact pulse is propagated and radiated in all directions within the board; but is
110 clear that the most direct path to the back of the board is the one which emerges at C_1. Other pulse fronts will reach the rear surface, for example at point C_2 marginally later. The path difference length is 'a' and the time difference is a divided by
115 the propagation velocity in the material concerned. An electronic circuit would be needed which can identify the segment into which point C_1 falls and suppresses the outputs from all the other segments. It is here suggested that piezo-
120 ceramic or similar pressure sensitive transducers are attached to the rear surface of the target board. The electric output from these transducers may then be applied to the operational amplifier circuit of Figure 4. This circuit, with very few
125 modifications, can readily be adapted for detecting and locating the first-most signal arriving at the back of the board and for generating a corresponding logical output available for score evaluation in a system such as
130 exemplified in Figure 5.

Because of the relatively small dimensions of the dart board segments the technique just outlined may not be applicable to dartboards and the magnetic detection system appears
5 preferable. When the margin of detection becomes too small differences inthe elasticity coefficient of the board material in different propagation directions may already upset the result. In the larger outdoor boards such
10 differences would not influence the score result.

Finally it should be mentioned that the proposed Score Translator system may also be connectable to a printout device for delivering a written record of the average and finishing scores
15 for teams and individual players where applicable.

Supplementary Notes

While the circuit Figure 4 ought to provide adequate sector identification if the noise background is low, it would nevertheless be
20 desirable to increase the input difference signals. To this end the effect of the magnetic field of the projectile in the wanted sector can be increased by making this sector (except a fringe margin around its periphery), magnetically conductive.
25 Ideally the full board depth should be made magnetically permeable. A simplified method is shown in Figures 7 and 8. The board consists of two plates, 12a and 12b, which are bonded together. The target board 12a has recesses 8, 9,
30 10, 11 (Figure 8 is a cross section, Figure 9 is view A—A) which exemplify the geometry to be applied to all the sectors of the Board; into these recesses a ferrite semi-hard rubber or the like substance is placed. It should have good
35 magnetic susceptibility. The reinforcement board 12b has holes allowing the prolonged cores 3 of the coils 4 to protrude and to touch the magnetic rubber fillings. The coil system is firmly riveted to a base iron plate which serves as a magnetic sink
40 and can be fixed to the board 12b via distance sleeves.

The electronic discrimination circuit would with advantage be fixed on the rear of base plate 1 to make connection links as short as possible.
45 As far as the described impact sensor method is concerned the same requires an electronic discriminator circuit similar to that shown in Figure 4; the difference being that the capacitor C1 is not connected to diode d_2 but with diode d_1.
50 Also, no negative input voltages need be compared because the dropping back of a dart or projectile will obviously not produce any signal at all. To detect at least those darts or projectiles which hit the metal dividing line between target
55 sectors, it is proposed to fix a pressure transducer to the metal. This transducer will not be affected by minor pulses but when there is a direct hit on the wire it will produce an output signal above an adjustable threshold and generate the 'Reset
60 Score' logic output required to cancel the preceding score released by the impact itself. In this way, rebounding projectiles will not produce a score.

To improve pulse discrimination on the basis of

65 Figure 6, it is proposed to produce on the rear side of the target board 12 (Fig. 9 and 10) a pattern of narrow deep grooves. The pattern is identical with the target sector boundary pattern. (Note grooves 20 and mechanical pulse transducers 22). These
70 slots may be filled with a substance having a lower specific weight than that of the board material.

A still further improvement of the wanted signal compared with the unwanted signal may
75 be obtained by iron inserts 21 pushed into the bottom of the grooves (see example groove 20a).

If a projectile tip n hits the board adjacent to the boundary wire 7 a portion of the impact pulse 24 is reflected by the heavier iron insert rails 21
80 and is again reflected from the top surface of the board, and reflected again therefrom in an inverted form causing a depression wave to travel towards the neighbouring sector. Here it will mix with other pulse lines and diminish the pulse
85 sensed by the transducer there. On the other hand, the wanted pulse on the left of the sector dividing wire will travel along line 23, and will thus not merely arrive earlier than on any neighbouring sector sensor but also with greater
90 strength. This will enable the modified Fig. 4 identifying circuit to produce the wanted unique output more safely.

The pressure transducer component 22 may optionally be a silicon-based integrated circuit
95 incorporating electronic piezo element and coupled amplifiers.

Claims

1. An Automatic Score Translator System in Projectile Games signified by means which detect
100 the dynamic and transitional effect exerted by the throw of a dart into a particular sector of the dart board.

2. An Automatic Score Translator System in Projectile Games as in claim 1 wherein the
105 detection means are mounted on or close to the rear of the dartboard or are inserted into the board.

3. An Automatic Score Translator System in Projectile Games as in claims 1 and 2 wherein the
110 propagation of the dynamic effects from the impact area to the corresponding detector is increased in directionality and decreased in dispersiveness by the incorporation of materials into the dart board construction which differ from
115 the basic dart board material, partly such material regions as would conduct the dynamic effect on a dart board sector preferentially to the corresponding sector detector; partly other material regions, including the sector dividers (2,
120 Fig. 2) which shield a neighbouring sector from receiving a substantial part of the dynamic effect.

4. An Automatic Score Translator System in Projectile Games as in claims 1—3 wherein the said dynamic effect derives from a magnetic field
125 emanating from the dart in flight.

5. Automatic Score Translator System for Projectile Games as in claim 4 wherein the darts are made of hollow shafts (S) into which an

essentially cylindrical permanent magnet (m) is
placed, and which imparts on the steel dart pin (n)
a longitudinal polarisation (Fig. 1).

5   6. Automatic Score Translator System in
Projectile Games wherein the detector is a
magnetic field sensor of the static or reactive
(inductor) type (3, 4, Fig. 2, 3).

      7. Automatic Score Translator System for
Projectile Games wherein the detector is a
10   mechanical impulse or vibration detector (22, Fig.
9, 10).

      8. An automatic score translator system in
Projectile Games as in claim 7 wherein the
vibration detector includes a piezo-electric sensor.

15   9. Automatic score translator systems for
Projectile Games as in claims, 1, 6 and 7 wherein
the rear of the dart board opposite the area of
each target sector is hollowed out to depth of at
least one quarter (8, 9, 10, 11, Figs 7, 8) of the
20   thickness of the board and the cavities are filled
with magnetically conductive material to increase
the field strength interacting with the magnetic
field sensors (3, 4).

      10. Automatic score translator systems for
25   Projectile Games wherein there is provided an
electrical impulse selector circuit which receives
input signals from various sector sensors
simultaneously or consecutively and which
consists of two pairs of operational amplifiers (A,
30   B) for each sector sensor pairs wherein the first
row responds only to positive sensor output
signals produced by an approaching dart and the
second row responds only to negative sensor
output signals produced by a dart which falls out.

35   11. Automatic score translator etc. as in claim
10 wherein all the operational amplifier outputs in
the first row (A, Fig. 4) are related to each other in
such a manner that only that with the marginally
largest positive input produces an amplified
40   output pulse whereas all the other amplifiers are
disabled and produce no output, and wherein the
signal produced by the thus selected operational
amplifier is applied to a score encoder (Fig. 5) for
encoding the score associated with the sector
45   from which the largest sensor output derives.

      12. Automatic score translator etc. as in claim
10 wherein all the operational amplifier outputs in
the second row (B, Fig. 4) are related to each
other in such a manner that only that with the
50   marginally largest negative input produces an
amplified output pulse whereas all the other
amplifiers are disabled and produce no output,
and wherein the signal produced by the thus
selected op. amp is applied to a score encoder
55   (Fig. 5) for cancelling the score associated with
the sector from which the largest sensor output
derives.

      13. Automatic Score Translator System in
Projectile Games which comprises a score display
60   panel for a total score and for the intermediate
score status of more than one pair of players, and
a keyboard (H) for setting the initial total score in
accordance with the conventional rules of the
game.

65   14. Automatic Score Translator System in
Projectile Games as in claim 13 in which system a
further keyboard (A—H) is provided for selecting
a particular player out of a number of quasi-
simultaneously playing pairs (A to H) and where
70   the instant score status for any one playing pair is
memorized in a memory register (F) which can be
called up for the selective display by using the
said keyboard (A—H) and which display (G)
would subsequently be altered by the player pair
75   in action according to the scores obtained by it
with the aid of the automatic score identifier
circuit (as shown in the example of Fig. 4), the
new score total being overwritten into the said
memory register sector of the player pair in the
80   register (F), to be ready for renewed call-up when
the turn again falls to that player pair to throw
their darts.

      15. Automatic Score Translator System in
Projectile Games as in claims 13 and 14 wherein
85   the display board (G) has two columns (x, z) for
each player in order to present a display for the
present instant throw score (for example in
column x) as well as the immediately preceding
instant total score (for example in column z); or, to
90   display the most recent total instant score side by
side with the immediately preceding instant total
score to give the viewer a clear picture of the
players performance.